

5 ESTIMATION OF DISTANCE TO OVERPRESSURE ENDPOINT FOR FLAMMABLE SUBSTANCES

In Chapter 5

- Methods to estimate the worst-case consequence distances for releases of flammable substances.
 - 5.1 Vapor cloud explosions of flammable substances that are not mixed with other substances, and
 - 5.2 Vapor cloud explosions of flammable substances in mixtures.

For the worst-case scenario involving a release of flammable gases and volatile flammable liquids, you must assume that the total quantity of the flammable substance forms a vapor cloud within the upper and lower flammability limits and the cloud detonates. As a conservative worst-case assumption, if you use the method presented here, you must assume that 10 percent of the flammable vapor in the cloud participates in the explosion. You need to estimate the consequence distance to an overpressure level of 1 pound per square inch (psi) from the explosion of the vapor cloud. An overpressure of 1 psi may cause partial demolition of houses, which can result in serious injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

This chapter presents a simple method for estimating the distance to the endpoint for a vapor cloud explosion of a regulated substance. The method presented here for analysis of vapor cloud explosions is based on a TNT-equivalent model. Other methods are available for analysis of vapor cloud explosions, including methods that consider site-specific conditions. You may use other methods for your worst-case analysis if you so choose, provided you assume the total quantity of flammable substance is in the cloud and use an endpoint of 1 psi. If you use a TNT-equivalent model, you must assume a yield factor of 10 percent. Appendix A includes references to documents and journal articles on vapor cloud explosions that may provide useful information on methods of analysis.

5.1 Flammable Substances Not in Mixtures

For the worst-case analysis of a regulated flammable substance that is not in a mixture with other substances, you may estimate the consequence distance for a given quantity of a regulated flammable substance using Reference Table 13. This table provides distances to 1 psi overpressure for vapor cloud explosions of quantities from 500 to 2,000,000 pounds. These distances were estimated by a TNT-equivalent model, Equation C-1 in Appendix C, Section C.1, using the worst-case assumptions described above and data provided in Exhibit C-1, Appendix C. If you prefer, you may calculate your worst-case consequence distance for flammable substances from the heat of combustion of the flammable substance and Equation C-1 or C-2.

Example 16. Vapor Cloud Explosion (Propane)

You have a tank containing 50,000 pounds of propane. From Reference Table 13, the distance to 1 psi overpressure is 0.3 miles for 50,000 pounds of propane.

Alternatively, you can calculate the distance to 1 psi using Equation C-2 from Appendix C:

$$D = 0.0081 \times [0.1 \times 50,000 \times (46,333/4,680)]^{1/3}$$

$$D = 0.3 \text{ miles}$$

5.2 Flammable Mixtures

If you have more than 10,000 pounds of a mixture of flammable substances that meets the criteria for listing under CAA section 112(r) (flash point below 22.8 °C (73 °F), boiling point below 37.8 °C (100 °F), National Fire Protection Association (NFPA) flammability hazard rating of 4), you may need to carry out a worst-case consequence analysis for the mixture. (If the mixture itself does not meet these criteria, it is not covered, and no analysis is required, even if the mixture contains one or more regulated substances.) You should carry out the analysis using the total quantity of all regulated flammable substance or substances in the mixture. Non-flammable components should not be included. However, if additional (non-regulated) flammable substances are present in the mixture, you should include them in the quantity used in the analysis.

For simplicity, you may carry out the worst-case analysis based on the predominant regulated flammable component of the mixture or a major component of the mixture with the highest heat of combustion if the whole vapor cloud consists of flammable substances (see Exhibit C-1, Appendix C for data on heat of combustion). Estimate the consequence distance from Reference Table 13 for the major component with the highest heat of combustion, assuming that the quantity in the cloud is the total quantity of the mixture. If you have a mixture in which the heats of combustion of the components do not differ significantly (e.g., a mixture of hydrocarbons), this method is likely to give reasonable results.

Alternatively, you may estimate the heat of combustion of the mixture from the heats of combustion of the components of the mixture using the method described in Appendix C, Section C.2, and then use Equation C-1 or C-2 in Appendix C to determine the vapor cloud explosion distance. This method may be appropriate if you have a mixture that includes components with significantly different heats of combustion (e.g., a mixture of hydrogen and hydrocarbons) that make up a significant portion of the mixture.

Examples 17 and 18 illustrate the two methods of analysis. In Example 17, the heat of combustion of the mixture is estimated, and the distance to the endpoint is calculated from Equation C-2. In Example 18, the component of the mixture with the highest heat of combustion is assumed to represent the entire mixture, and the distance to the endpoint is read from Reference Table 13. For the mixture of two hydrocarbons used in the example, the methods give very similar results.

Example 17. Estimating Heat of Combustion of Mixture for Vapor Cloud Explosion Analysis

You have a mixture of 8,000 pounds of ethylene (the reactant) and 2,000 pounds of isobutane (a catalyst carrier). To carry out the worst-case analysis, estimate the heat of combustion of the mixture from the heats of combustion of the components of the mixture. (Ethylene heat of combustion = 47,145 kilojoules per kilogram; isobutane heat of combustion = 45,576). Using Equation C-3, Appendix C:

$$HC_m = \left[\frac{(8,000/2.2)}{(10,000/2.2)} \times 47,145 \right] + \left[\frac{(2,000/2.2)}{(10,000/2.2)} \times 45,576 \right]$$

$$HC_m = (37,716) + (9,115)$$

$$HC_m = 46,831 \text{ kilojoules per kilogram}$$

Now use the calculated heat of combustion for the mixture in Equation C-2 to calculate the distance to 1 psi overpressure for vapor cloud explosion.

$$D = 0.0081 \times [0.1 \times 10,000 \times (46,831/4,680)]^{1/4}$$

$$D = 0.2 \text{ miles}$$

Example 18. Vapor Cloud Explosion of Flammable Mixture (Ethylene and Isobutane)

You have 10,000 pounds of a mixture of ethylene (the reactant) and isobutane (a catalyst carrier). To carry out the worst-case analysis, assume the quantity in the cloud is the total quantity of the mixture. Use data for ethylene because it is the component with the highest heat of combustion. (Ethylene heat of combustion = 47,145 kilojoules per kilogram; isobutane heat of combustion = 45,576, from Exhibit C-1, Appendix C). From Reference Table 13, the distance to 1 psi overpressure is 0.2 miles for 10,000 pounds of ethylene; this distance would also apply to the 10,000-pound mixture of ethylene and isobutane.

Reference Table 1
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
10-Minute Release, Rural Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 4.4	0.1
4.4 - 37	0.2
37 - 97	0.3
97 - 180	0.4
180 - 340	0.6
340 - 530	0.8
530 - 760	1.0
760 - 1,000	1.2
1,000 - 1,500	1.4
1,500 - 1,900	1.6
1,900 - 2,400	1.8
2,400 - 2,900	2.0
2,900 - 3,500	2.2
3,500 - 4,400	2.4
4,400 - 5,100	2.6
5,100 - 5,900	2.8
5,900 - 6,800	3.0
6,800 - 7,700	3.2
7,700 - 9,000	3.4
9,000 - 10,000	3.6
10,000 - 11,000	3.8
11,000 - 12,000	4.0
12,000 - 14,000	4.2
14,000 - 15,000	4.4
15,000 - 16,000	4.6

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
16,000 - 18,000	4.8
18,000 - 19,000	5.0
19,000 - 21,000	5.2
21,000 - 23,000	5.4
23,000 - 24,000	5.6
24,000 - 26,000	5.8
26,000 - 28,000	6.0
28,000 - 29,600	6.2
29,600 - 35,600	6.8
35,600 - 42,000	7.5
42,000 - 48,800	8.1
48,800 - 56,000	8.7
56,000 - 63,600	9.3
63,600 - 71,500	9.9
71,500 - 88,500	11
88,500 - 107,000	12
107,000 - 126,000	14
126,000 - 147,000	15
147,000 - 169,000	16
169,000 - 191,000	17
191,000 - 215,000	19
215,000 - 279,000	22
279,000 - 347,000	25
>347,000	>25*

*Report distance as 25 miles

Reference Table 2
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
60-Minute Release, Rural Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 5.5	0.1	7,400 - 7,700	4.8
5.5 - 46	0.2	7,700 - 8,100	5.0
46 - 120	0.3	8,100 - 8,500	5.2
120 - 220	0.4	8,500 - 8,900	5.4
220 - 420	0.6	8,900 - 9,200	5.6
420 - 650	0.8	9,200 - 9,600	5.8
650 - 910	1.0	9,600 - 10,000	6.0
910 - 1,200	1.2	10,000 - 10,400	6.2
1,200 - 1,600	1.4	10,400 - 11,700	6.8
1,600 - 1,900	1.6	11,700 - 13,100	7.5
1,900 - 2,300	1.8	13,100 - 14,500	8.1
2,300 - 2,600	2.0	14,500 - 15,900	8.7
2,600 - 2,900	2.2	15,900 - 17,500	9.3
2,900 - 3,400	2.4	17,500 - 19,100	9.9
3,400 - 3,700	2.6	19,100 - 22,600	11
3,700 - 4,100	2.8	22,600 - 26,300	12
4,100 - 4,400	3.0	26,300 - 30,300	14
4,400 - 4,800	3.2	30,300 - 34,500	15
4,800 - 5,200	3.4	34,500 - 38,900	16
5,200 - 5,600	3.6	38,900 - 43,600	17
5,600 - 5,900	3.8	43,600 - 48,400	19
5,900 - 6,200	4.0	48,400 - 61,500	22
6,200 - 6,700	4.2	61,500 - 75,600	25
6,700 - 7,000	4.4	>75,600	>25*
7,000 - 7,400	4.6		

*Report distance as 25 miles

Reference Table 3
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
10-minute Release, Urban Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 21	0.1	76,000 - 83,000	4.8
21 - 170	0.2	83,000 - 90,000	5.0
170 - 420	0.3	90,000 - 100,000	5.2
420 - 760	0.4	100,000 - 110,000	5.4
760 - 1,400	0.6	110,000 - 120,000	5.6
1,400 - 2,100	0.8	120,000 - 130,000	5.8
2,100 - 3,100	1.0	130,000 - 140,000	6.0
3,100 - 4,200	1.2	140,000 - 148,000	6.2
4,200 - 6,100	1.4	148,000 - 183,000	6.8
6,100 - 7,800	1.6	183,000 - 221,000	7.5
7,800 - 9,700	1.8	221,000 - 264,000	8.1
9,700 - 12,000	2.0	264,000 - 310,000	8.7
12,000 - 14,000	2.2	310,000 - 361,000	9.3
14,000 - 18,000	2.4	361,000 - 415,000	9.9
18,000 - 22,000	2.6	415,000 - 535,000	11
22,000 - 25,000	2.8	535,000 - 671,000	12
25,000 - 29,000	3.0	671,000 - 822,000	14
29,000 - 33,000	3.2	822,000 - 990,000	15
33,000 - 39,000	3.4	990,000 - 1,170,000	16
39,000 - 44,000	3.6	1,170,000 - 1,370,000	17
44,000 - 49,000	3.8	1,370,000 - 1,590,000	19
49,000 - 55,000	4.0	1,590,000 - 2,190,000	22
55,000 - 63,000	4.2	2,190,000 - 2,890,000	25
63,000 - 69,000	4.4	>2,890,000	>25*
69,000 - 76,000	4.6		

*Report distance as 25 miles

Reference Table 4
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
60-Minute Release, Urban Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 26	0.1	34,000 - 36,000	4.8
26 - 210	0.2	36,000 - 38,000	5.0
210 - 530	0.3	38,000 - 41,000	5.2
530 - 940	0.4	41,000 - 43,000	5.4
940 - 1,700	0.6	43,000 - 45,000	5.6
1,700 - 2,600	0.8	45,000 - 47,000	5.8
2,600 - 3,700	1.0	47,000 - 50,000	6.0
3,700 - 4,800	1.2	50,000 - 52,200	6.2
4,800 - 6,400	1.4	52,200 - 60,200	6.8
6,400 - 7,700	1.6	60,200 - 68,900	7.5
7,700 - 9,100	1.8	68,900 - 78,300	8.1
9,100 - 11,000	2.0	78,300 - 88,400	8.7
11,000 - 12,000	2.2	88,400 - 99,300	9.3
12,000 - 14,000	2.4	99,300 - 111,000	9.9
14,000 - 16,000	2.6	111,000 - 137,000	11
16,000 - 17,000	2.8	137,000 - 165,000	12
17,000 - 19,000	3.0	165,000 - 197,000	14
19,000 - 21,000	3.2	197,000 - 232,000	15
21,000 - 23,000	3.4	232,000 - 271,000	16
23,000 - 24,000	3.6	271,000 - 312,000	17
24,000 - 26,000	3.8	312,000 - 357,000	19
26,000 - 28,000	4.0	357,000 - 483,000	22
28,000 - 30,000	4.2	483,000 - 629,000	25
30,000 - 32,000	4.4	>629,000	>25*
32,000 - 34,000	4.6		

*Report distance as 25 miles

Reference Table 5
Dense Gas Distances to Toxic Endpoint
10-minute Release, Rural Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	2.2	1.7	1.5	1.1	0.8	0.7	0.5	0.5	0.3	0.2	0.2	0.2	0.1	0.1	#	#
2	3.0	2.4	2.1	1.5	1.1	0.9	0.7	0.7	0.4	0.3	0.3	0.2	0.2	0.1	<0.1	<0.1
5	4.8	3.7	3.0	2.2	1.7	1.5	1.2	1.0	0.7	0.5	0.4	0.3	0.3	0.2	0.1	0.1
10	6.8	5.0	4.2	3.0	2.4	2.1	1.7	1.4	1.0	0.7	0.6	0.5	0.4	0.2	0.2	0.1
30	11	8.7	6.8	5.2	3.9	3.4	2.8	2.4	1.7	1.3	1.1	0.9	0.7	0.4	0.3	0.2
50	14	11	9.3	6.8	5.0	4.2	3.5	3.0	2.2	1.7	1.4	1.1	0.9	0.6	0.4	0.3
100	19	15	12	8.7	6.8	5.8	4.8	4.2	2.9	2.2	1.9	1.6	1.3	0.8	0.5	0.4
150	24	18	15	11	8.1	6.8	5.7	5.0	3.6	2.7	2.3	1.9	1.6	0.9	0.6	0.5
250	>25	22	19	14	11	8.7	7.4	6.2	4.5	3.4	2.8	2.3	2.0	1.2	0.8	0.6
500	*	>25	>25	19	14	12	9.9	8.7	6.2	4.7	3.8	3.1	2.7	1.6	1.1	0.9
750	*	*	*	23	17	15	12	11	7.4	5.5	4.5	3.7	3.2	1.9	1.3	1.0
1,000	*	*	*	>25	20	17	14	12	8.1	6.2	5.2	4.2	3.6	2.2	1.4	1.1
1,500	*	*	*	*	24	20	16	14	9.9	7.4	6.2	5.0	4.3	2.5	1.7	1.3
2,000	*	*	*	*	>25	23	19	16	11	8.7	6.8	5.6	4.8	2.9	1.9	1.5
2,500	*	*	*	*	*	>25	20	18	12	9.3	8.1	6.2	5.3	3.2	2.1	1.6
3,000	*	*	*	*	*	*	23	20	14	9.9	8.7	6.8	5.6	3.4	2.2	1.7
4,000	*	*	*	*	*	*	>25	22	16	11	9.3	7.4	6.2	3.8	2.5	2.0
5,000	*	*	*	*	*	*	*	25	17	13	11	8.7	6.8	4.2	2.7	2.1
7,500	*	*	*	*	*	*	*	>25	20	15	12	9.9	8.7	4.9	3.2	2.5
10,000	*	*	*	*	*	*	*	*	24	17	14	11	9.3	5.5	3.6	2.8
15,000	*	*	*	*	*	*	*	*	>25	20	17	13	11	6.2	4.2	3.2
20,000	*	*	*	*	*	*	*	*	*	23	19	15	12	7.4	4.7	3.7
50,000	*	*	*	*	*	*	*	*	*	>25	>25	21	18	10	6.6	5.0
75,000	*	*	*	*	*	*	*	*	*	*	*	>25	21	12	7.6	5.8
100,000	*	*	*	*	*	*	*	*	*	*	*	*	24	13	8.5	6.4
150,000	*	*	*	*	*	*	*	*	*	*	*	*	>25	15	9.8	7.4
200,000	*	*	*	*	*	*	*	*	*	*	*	*	*	17	11	8.2

* > 25 miles (report distance as 25 miles)

<0.1 mile (report distance as 0.1 mile)

Reference Table 6
Dense Gas Distances to Toxic Endpoint
60-minute Release, Rural Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	3.7	2.7	2.2	1.4	1.0	0.8	0.6	0.5	0.3	0.2	0.2	0.1	0.1	<0.1	#	#
2	5.3	4.0	3.2	2.2	1.6	1.2	1.0	0.8	0.5	0.4	0.3	0.2	0.2	0.1	<0.1	<0.1
5	8.7	6.8	5.3	3.7	2.7	2.2	1.7	1.4	0.9	0.6	0.5	0.4	0.3	0.2	0.1	0.1
10	12	9.3	8.1	5.3	4.0	3.3	2.7	2.2	1.4	1.0	0.8	0.6	0.5	0.3	0.2	0.1
30	22	16	14	9.9	7.4	6.1	4.9	4.1	2.9	2.1	1.6	1.2	1.0	0.5	0.3	0.2
50	>25	21	18	12	9.3	8.1	6.2	5.4	3.8	2.7	2.2	1.7	1.4	0.7	0.4	0.3
100	*	>25	>25	18	13	11	9.3	7.4	5.5	4.0	3.2	2.5	2.1	1.1	0.7	0.5
150	*	*	*	22	17	14	11	9.9	6.8	4.9	4.0	3.1	2.7	1.4	0.9	0.6
250	*	*	*	>25	22	18	14	12	8.7	6.2	5.2	4.1	3.5	1.9	1.2	0.9
500	*	*	*	*	>25	25	20	17	12	9.3	7.4	5.8	5.0	2.9	1.8	1.3
750	*	*	*	*	*	>25	25	22	15	11	9.3	7.4	6.1	3.5	2.2	1.7
1,000	*	*	*	*	*	*	>25	25	17	12	11	8.1	6.8	4.0	2.6	2.0
1,500	*	*	*	*	*	*	*	>25	20	16	12	9.9	8.7	5.0	3.2	2.5
2,000	*	*	*	*	*	*	*	*	24	17	14	11	9.9	5.7	3.7	2.9
2,500	*	*	*	*	*	*	*	*	>25	20	16	13	11	6.2	4.2	3.2
3,000	*	*	*	*	*	*	*	*	*	21	17	14	12	6.8	4.5	3.5
4,000	*	*	*	*	*	*	*	*	*	24	20	16	14	8.1	5.2	4.0
5,000	*	*	*	*	*	*	*	*	*	>25	22	17	15	8.7	5.7	4.4
7,500	*	*	*	*	*	*	*	*	*	*	>25	21	18	11	6.8	5.2
10,000	*	*	*	*	*	*	*	*	*	*	*	24	20	12	7.4	6.0
15,000	*	*	*	*	*	*	*	*	*	*	*	>25	24	14	9.3	6.8
20,000	*	*	*	*	*	*	*	*	*	*	*	*	>25	16	9.9	8.1
50,000	*	*	*	*	*	*	*	*	*	*	*	*	*	22	14	11
75,000	*	*	*	*	*	*	*	*	*	*	*	*	*	>25	17	13
100,000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	18	14
150,000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21	16
200,000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	23	18

* > 25 miles (report distance as 25 miles)

<0.1 mile (report distance as 0.1 mile)

Reference Table 7
Dense Gas Distances to Toxic Endpoint
10-minute Release, Urban Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	1.6	1.2	1.1	0.7	0.6	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	#	#	#
2	2.2	1.7	1.4	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	<0.1	#	#
5	3.5	2.7	2.2	1.6	1.2	1.0	0.8	0.7	0.5	0.4	0.3	0.2	0.2	0.1	<0.1	#
10	4.9	3.8	3.1	2.2	1.7	1.4	1.2	1.0	0.7	0.5	0.4	0.3	0.2	0.1	0.1	<0.1
30	8.1	6.2	5.3	3.7	2.9	2.4	2.0	1.7	1.2	0.9	0.7	0.6	0.4	0.2	0.1	0.1
50	11	8.1	6.8	4.8	3.7	3.1	2.5	2.1	1.5	1.1	0.9	0.7	0.6	0.3	0.2	0.1
100	15	11	9.3	6.8	5.2	4.2	3.5	3.0	2.1	1.6	1.3	1.0	0.9	0.5	0.3	0.2
150	19	14	12	8.1	6.1	5.2	4.3	3.6	2.5	1.9	1.6	1.2	1.1	0.6	0.4	0.2
250	24	18	15	11	8.1	6.8	5.4	4.6	3.3	2.4	2.0	1.6	1.4	0.7	0.5	0.3
500	>25	>25	21	15	11	9.3	7.4	6.2	4.5	3.4	2.8	2.2	1.9	1.1	0.7	0.5
750	*	*	>25	18	14	11	9.3	8.1	5.5	4.1	3.3	2.6	2.2	1.3	0.8	0.6
1,000	*	*	*	21	16	13	11	9.3	6.2	4.6	3.8	3.0	2.5	1.5	0.9	0.7
1,500	*	*	*	>25	19	16	12	11	7.4	5.6	4.6	3.7	3.0	1.7	1.1	0.8
2,000	*	*	*	*	22	18	15	12	8.7	6.2	5.2	4.1	3.5	2.0	1.3	0.9
2,500	*	*	*	*	24	20	16	14	9.9	6.8	5.8	4.7	3.8	2.2	1.4	1.1
3,000	*	*	*	*	>25	22	18	16	11	7.4	6.2	5.0	4.2	2.4	1.6	1.2
4,000	*	*	*	*	*	25	20	17	12	8.7	6.8	5.6	4.8	2.7	1.7	1.3
5,000	*	*	*	*	*	>25	23	20	14	9.9	8.1	6.2	5.3	3.0	1.9	1.4
7,500	*	*	*	*	*	*	>25	24	16	12	9.9	7.4	6.2	3.6	2.3	1.7
10,000	*	*	*	*	*	*	*	>25	19	14	11	8.7	7.4	4.1	2.6	2.0
15,000	*	*	*	*	*	*	*	*	22	16	13	11	8.7	4.9	3.1	2.3
20,000	*	*	*	*	*	*	*	*	>25	19	15	12	9.9	5.5	3.5	2.7
50,000	*	*	*	*	*	*	*	*	*	>25	23	17	15	8.1	5.1	3.8
75,000	*	*	*	*	*	*	*	*	*	*	>25	21	17	9.6	6.0	4.5
100,000	*	*	*	*	*	*	*	*	*	*	*	24	20	11	6.8	5.1
150,000	*	*	*	*	*	*	*	*	*	*	*	>25	23	13	8.1	6.1
200,000	*	*	*	*	*	*	*	*	*	*	*	*	>25	14	8.9	6.7

* > 25 miles (report distance as 25 miles)

<0.1 mile (report distance as 0.1 mile)

Reference Table 8
Dense Gas Distances to Toxic Endpoint
60-minute Release, Urban Conditions, F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	2.6	1.9	1.5	1.1	0.7	0.6	0.4	0.4	0.2	0.2	0.1	0.1	0.1	#	#	#
2	3.8	2.9	2.3	1.5	1.1	0.9	0.7	0.6	0.4	0.2	0.2	0.1	0.1	<0.1	#	#
5	6.2	4.7	3.9	2.6	1.9	1.5	1.2	0.9	0.6	0.4	0.3	0.2	0.2	0.1	<0.1	#
10	9.3	6.8	5.6	3.9	2.9	2.3	1.8	1.5	0.9	0.7	0.5	0.4	0.3	0.2	0.1	<0.1
30	16	12	9.9	7.4	5.3	4.3	3.4	2.9	1.9	1.3	1.0	0.7	0.6	0.3	0.2	0.1
50	22	16	14	9.3	6.8	5.7	4.5	3.8	2.6	1.8	1.4	1.1	0.9	0.4	0.2	0.2
100	>25	24	20	14	9.9	8.1	6.8	5.7	3.8	2.7	2.2	1.7	1.4	0.7	0.4	0.3
150	*	>25	24	17	12	11	8.1	6.8	4.8	3.5	2.8	2.2	1.8	0.9	0.5	0.3
250	*	*	>25	22	16	14	11	9.3	6.2	4.5	3.7	2.9	2.4	1.2	0.7	0.5
500	*	*	*	>25	24	19	16	13	9.3	6.8	5.4	4.2	3.5	1.9	1.1	0.7
750	*	*	*	*	>25	24	19	16	11	8.1	6.8	5.2	4.3	2.4	1.4	1.0
1,000	*	*	*	*	*	>25	22	19	13	9.3	7.4	6.0	5.0	2.8	1.6	1.2
1,500	*	*	*	*	*	*	>25	24	16	12	9.3	7.4	6.2	3.4	2.1	1.5
2,000	*	*	*	*	*	*	*	>25	19	13	11	8.7	7.4	4.0	2.5	1.8
2,500	*	*	*	*	*	*	*	*	20	15	12	9.3	8.1	4.5	2.8	2.1
3,000	*	*	*	*	*	*	*	*	22	16	13	11	8.7	4.9	3.0	2.2
4,000	*	*	*	*	*	*	*	*	>25	19	16	12	9.9	5.6	3.5	2.6
5,000	*	*	*	*	*	*	*	*	*	21	17	14	11	6.2	4.0	3.0
7,500	*	*	*	*	*	*	*	*	*	>25	20	16	14	7.4	4.8	3.6
10,000	*	*	*	*	*	*	*	*	*	*	24	19	16	8.7	5.5	4.2
15,000	*	*	*	*	*	*	*	*	*	*	>25	22	19	11	6.8	5.1
20,000	*	*	*	*	*	*	*	*	*	*	*	>25	21	12	7.4	5.8
50,000	*	*	*	*	*	*	*	*	*	*	*	*	>25	18	11	8.7
75,000	*	*	*	*	*	*	*	*	*	*	*	*	*	21	13	10
100,000	*	*	*	*	*	*	*	*	*	*	*	*	*	24	15	11
150,000	*	*	*	*	*	*	*	*	*	*	*	*	*	>25	18	14
200,000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	20	15

* > 25 miles (report distance as 25 miles)

<0.1 mile (report distance as 0.1 mile)

Reference Table 9
Distances to Toxic Endpoint for Anhydrous Ammonia Liquefied Under Pressure
F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1	0.1	<0.1*
2	0.1	0.1
5	0.1	0.1
10	0.2	0.1
15	0.2	0.2
20	0.3	0.2
30	0.3	0.2
40	0.4	0.3
50	0.4	0.3
60	0.5	0.3
70	0.5	0.3
80	0.5	0.4
90	0.6	0.4
100	0.6	0.4
150	0.7	0.5
200	0.8	0.6
250	0.9	0.6
300	1.0	0.7
400	1.2	0.8
500	1.3	0.9
600	1.4	0.9
700	1.5	1.0
750	1.6	1.0
800	1.6	1.1
900	1.7	1.2

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1,000	1.8	1.2
1,500	2.2	1.5
2,000	2.6	1.7
2,500	2.9	1.9
3,000	3.1	2.0
4,000	3.6	2.3
5,000	4.0	2.6
6,000	4.4	2.8
7,000	4.7	3.1
7,500	4.9	3.2
8,000	5.1	3.3
9,000	5.4	3.4
10,000	5.6	3.6
15,000	6.9	4.4
20,000	8.0	5.0
25,000	8.9	5.6
30,000	9.7	6.1
40,000	11	7.0
50,000	12	7.8
75,000	15	9.5
100,000	18	10
150,000	22	13
200,000	**	15
250,000	**	17
750,000	**	**

*Report distance as 0.1 mile

** More than 25 miles (report distance as 25 miles)

Reference Table 10
Distances to Toxic Endpoint for Non-liquefied Ammonia, Ammonia Liquefied by Refrigeration, or
Aqueous Ammonia
F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1	0.1	<0.1*
2	0.1	
5	0.1	
10	0.2	0.1
15	0.2	0.1
20	0.3	0.1
30	0.3	0.1
40	0.4	0.1
50	0.4	0.1
60	0.4	0.2
70	0.5	0.2
80	0.5	0.2
90	0.5	0.2
100	0.6	0.2
150	0.7	0.2
200	0.8	0.3
250	0.8	0.3
300	0.9	0.3
400	1.1	0.4
500	1.2	0.4
600	1.3	0.4
700	1.4	0.5
750	1.4	0.5
800	1.5	0.5
900	1.5	0.6

*Report distance as 0.1 mile

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1,000	1.6	0.6
1,500	2.0	0.7
2,000	2.2	0.8
2,500	2.5	0.9
3,000	2.7	1.0
4,000	3.1	1.1
5,000	3.4	1.2
6,000	3.7	1.3
7,000	4.0	1.4
7,500	4.1	1.5
8,000	4.2	1.5
9,000	4.5	1.6
10,000	4.7	1.7
15,000	5.6	2.0
20,000	6.5	2.4
25,000	7.2	2.6
30,000	7.8	2.8
40,000	8.9	3.3
50,000	9.8	3.6
75,000	12	4.4
100,000	14	5.0
150,000	16	6.1
200,000	19	7.0
250,000	21	7.8
750,000	**	13

** More than 25 miles (report distance as 25 miles)

Reference Table 11
Distances to Toxic Endpoint for Chlorine
F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1	0.2	0.1
2	0.3	0.1
5	0.5	0.2
10	0.7	0.3
15	0.8	0.4
20	1.0	0.4
30	1.2	0.5
40	1.4	0.6
50	1.5	0.6
60	1.7	0.7
70	1.8	0.8
80	1.9	0.8
90	2.0	0.9
100	2.2	0.9
150	2.6	1.2
200	3.0	1.3
250	3.4	1.5
300	3.7	1.6
400	4.2	1.9
500	4.7	2.1
600	5.2	2.3
700	5.6	2.5

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
750	5.8	2.6
800	5.9	2.7
900	6.3	2.9
1,000	6.6	3.0
1,500	8.1	3.8
2,000	9.3	4.4
2,500	10	4.9
3,000	11	5.4
4,000	13	6.2
5,000	14	7.0
6,000	16	7.6
7,000	17	8.3
7,500	18	8.6
8,000	18	8.9
9,000	19	9.4
10,000	20	9.9
15,000	25	12
20,000	*	14
25,000	*	16
30,000	*	18
40,000	*	20
50,000	*	*

* More than 25 miles (report distance as 25 miles)

Reference Table 12
Distances to Toxic Endpoint for Anhydrous Sulfur Dioxide
F Stability, Wind Speed 1.5 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
1	0.2	0.1
2	0.2	0.1
5	0.4	0.2
10	0.6	0.2
15	0.7	0.3
20	0.9	0.4
30	1.1	0.5
40	1.3	0.5
50	1.4	0.6
60	1.6	0.7
70	1.8	0.7
80	1.9	0.8
90	2.0	0.8
100	2.1	0.9
150	2.7	1.1
200	3.1	1.3
250	3.6	1.4
300	3.9	1.6
400	4.6	1.9
500	5.2	2.1
600	5.8	2.3
700	6.3	2.5

Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban
750	6.6	2.6
800	6.8	2.7
900	7.2	2.9
1,000	7.7	3.1
1,500	9.6	3.8
2,000	11	4.5
2,500	13	5.0
3,000	14	5.6
4,000	17	6.5
5,000	19	7.3
6,000	21	8.1
7,000	23	8.8
7,500	24	9.1
8,000	25	9.5
9,000	*	10
10,000	*	11
15,000	*	13
20,000	*	16
25,000	*	18
30,000	*	19
40,000	*	23
50,000	*	*

* More than 25 miles (report distance as 25 miles)

Reference Table 13
Distance to Overpressure of 1.0 psi for Vapor Cloud Explosions of 500 - 2,000,000 Pounds of Regulated Flammable Substances
Based on TNT Equivalent Method, 10 Percent Yield Factor

Quantity in Cloud (pounds)		500	2,000	5,000	10,000	20,000	50,000	100,000	200,000	500,000	1,000,000	2,000,000
CAS No.	Chemical Name	Distance (Miles) to 1 psi Overpressure										
75-07-0	Acetaldehyde	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8
74-86-2	Acetylene	0.07	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	1.0
598-73-2	Bromotrifluoroethylene	0.02	0.04	0.05	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4
106-99-0	1,3-Butadiene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
106-97-8	Butane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
25167-67-3	Butene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
590-18-1	2-Butene-cis	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
624-64-6	2-Butene-trans	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
106-98-9	1-Butene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
107-01-7	2-Butene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
463-58-1	Carbon oxysulfide	0.04	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6
7791-21-1	Chlorine monoxide	0.02	0.03	0.04	0.05	0.06	0.08	0.1	0.1	0.2	0.2	0.3
590-21-6	1-Chloropropylene	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
557-98-2	2-Chloropropylene	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
460-19-5	Cyanogen	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
75-19-4	Cyclopropane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
4109-96-0	Dichlorosilane	0.04	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6
75-37-6	Difluoroethane	0.04	0.06	0.09	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6
124-40-3	Dimethylamine	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9
463-82-1	2,2-Dimethylpropane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
74-84-0	Ethane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
107-00-6	Ethyl acetylene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
75-04-7	Ethylamine	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9

Reference Table 13 (continued)

Quantity in Cloud (pounds)		500	2,000	5,000	10,000	20,000	50,000	100,000	200,000	500,000	1,000,000	2,000,000
CAS No.	Chemical Name	Distance (Miles) to 1 psi Overpressure										
75-00-3	Ethyl chloride	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
74-85-1	Ethylene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	1.0
60-29-7	Ethyl ether	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9
75-08-1	Ethyl mercaptan	0.05	0.09	0.1	0.2	0.2	0.2	0.3	0.4	0.5	0.7	0.9
109-95-5	Ethyl nitrite	0.05	0.07	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.6	0.7
1333-74-0	Hydrogen	0.09	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.9	1.1	1.4
75-28-5	Isobutane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
78-78-4	Isopentane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
78-79-5	Isoprene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
75-31-0	Isopropylamine	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9
75-29-6	Isopropyl chloride	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
74-82-8	Methane	0.07	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	1.0
74-89-5	Methylamine	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9
563-45-1	3-Methyl-1-butene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
563-46-2	2-Methyl-1-butene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
115-10-6	Methyl ether	0.05	0.09	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.7	0.9
107-31-3	Methyl formate	0.04	0.07	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7
115-11-7	2-Methylpropene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
504-60-9	1,3-Pentadiene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
109-66-0	Pentane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
109-67-1	1-Pentene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
646-04-8	2-Pentene, (E)-	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
627-20-3	2-Pentene, (Z)-	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
463-49-0	Propadiene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0

Reference Table 13 (continued)

Quantity in Cloud (pounds)		500	2,000	5,000	10,000	20,000	50,000	100,000	200,000	500,000	1,000,000	2,000,000
CAS No.	Chemical Name	Distance (Miles) to 1 psi Overpressure										
74-98-6	Propane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
115-07-1	Propylene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
74-99-7	Propyne	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
7803-62-5	Silane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
116-14-3	Tetrafluoroethylene	0.02	0.03	0.04	0.05	0.07	0.09	0.1	0.1	0.2	0.2	0.3
75-76-3	Tetramethylsilane	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
10025-78-2	Trichlorosilane	0.03	0.04	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.4
79-38-9	Trifluorochloroethylene	0.02	0.03	0.05	0.06	0.07	0.1	0.1	0.2	0.2	0.3	0.3
75-50-3	Trimethylamine	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.6	0.8	1.0
689-97-4	Vinyl acetylene	0.06	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	1.0
75-01-4	Vinyl chloride	0.05	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8
109-92-2	Vinyl ethyl ether	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9
75-02-5	Vinyl fluoride	0.02	0.04	0.05	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4
75-35-4	Vinylidene chloride	0.04	0.06	0.08	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6
75-38-7	Vinylidene fluoride	0.04	0.06	0.09	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6
107-25-5	Vinyl methyl ether	0.06	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.7	0.9